Antimicrobial finishes on Textiles

The conventional fibers and polymers not only show no resistance against micro-organisms and materials generated from their metabolism but also are most commonly prone to accumulation, multiplication and proliferation of micro-organisms into their surrounding environment.

In fact, several factors such as suitable temperature and humidity, presence of dust, soil, spilled food and drink stains, skin dead cells, sweat and oil secretions of skin gland, also finishing materials on the textile surfaces can make textile optimal enrichment cultures for a rapid multiplication of micro-organisms. Regarding to rapid improvement of hygienic living standard, controlling of aforementioned terrible effect is necessary.

Therefore, many researches have focused on the anti-bacterial modification of textiles.

Anti-microbial agents are used to prevent three undesirable effects in textiles.

The first includes the degradation phenomena like coloring, staining and deterioration of fibers.

Because of their dye degradation potential, even some fungus can be used for removing dye from textile effluent.

The second one produces unpleasant odor and the third effect is the increase of potential health risks.

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Considering the chemical and structural nature of antimicrobial agents, the following mechanisms lead to reduced microbial growth and cell death as summarized in

– Inhibition of cell wall synthesis
– Inhibition of protein synthesis
– Inhibition of enzyme action
– Inhibition of nucleic acid synthesis
– DNA damage
– Inhibition of metabolic pathways
– Interference with cell membrane integrity
– Interference with cell membrane permeability
– Cell wall damage

COMMON TEXTILE ANTIMICROBIAL AGENTS

Quaternary ammonium compounds with linear alkyl ammonium compounds composed of a hydrophobic alkyl chain and a hydrophilic part such as 3-(trihydroxysilyl) propy (dimethyl-octdecyl ammonium chloride have been mainly applied in natural fibers such as wool forming covalent bonds with the substrate or in synthetic fibers such as nylon through ionic interactions.

Alkyl chain length, presence of the perfluorinated group, and number of cationic ammonium groups affect the antibacterial efficiencies. Interaction of surface positive charges and cell membrane negative charges, interfering cell membrane permeability and leakage are among the possible antimicrobial mechanism, which causes cell damage, denaturation of proteins, and inhibition of DNA production avoiding multiplication.

Polybiguanides (polycationic amines composed of cationic biguanide repeat units separated by aliphatic chains) such as polyhexamethylene biguanide shortly named as PHMB are promising antibacterial agents for natural and synthetic fibers and mainly act via electrostatic attraction with the negatively charged bacterial cell interfering membrane permeability.

Metal nanoparticles

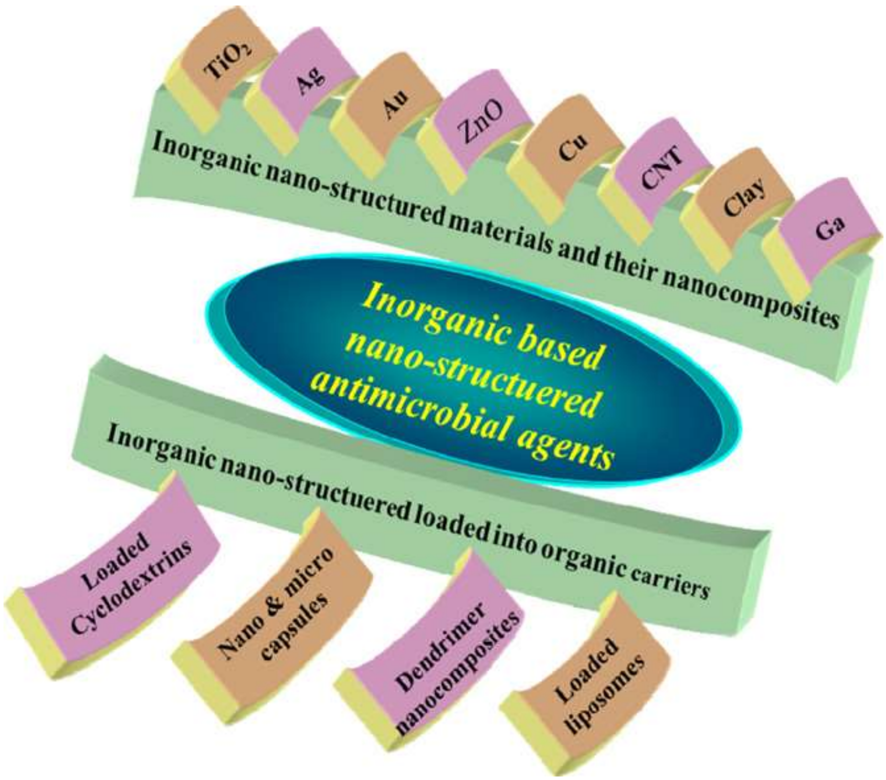
Silver (Ag)

Silver nanoparticles have a reputation for antibacterial activities and their therapeutic property has been proved against a broad range of disease causing microorganisms.

They can be synthesized through a variety of methods ranging from simple chemical reduction processes to **photochemical, biochemical, sonochemical**, and Tollens' reagent methods.

The potentiating effect of silver nanoparticles in killing the microorganisms is generally related to silver metal ions and their small particle size and high specific surface area, which allow close interaction with microbial membranes.

Attachment of silver ions or nanoparticles to the bacteria due to electrostatic interaction with negative charge of bacterial cell wall, damage to the lipids, proteins and DNA of the microorganisms are the main antibacterial mechanisms of silver nanoparticles.



(1) Inorganic nano-structured materials and their composites.
(2) Inorganic nano-structured loaded organic carriers.

The inorganic nano-structured materials include titanium dioxide, silver, zinc oxide, copper, gallium, gold nano-particles, carbon nanotubes, nano-layered clay, and their nano-composites.

The inorganic nano-structured loaded in organic materials include cyclodextrin loaded with inorganic materials, nano- and micro-capsules having inorganic nano-particles, metallic den- drimer nano-composites and inorganic nano-particles loaded in liposomes.

TiO_2 nano-particles

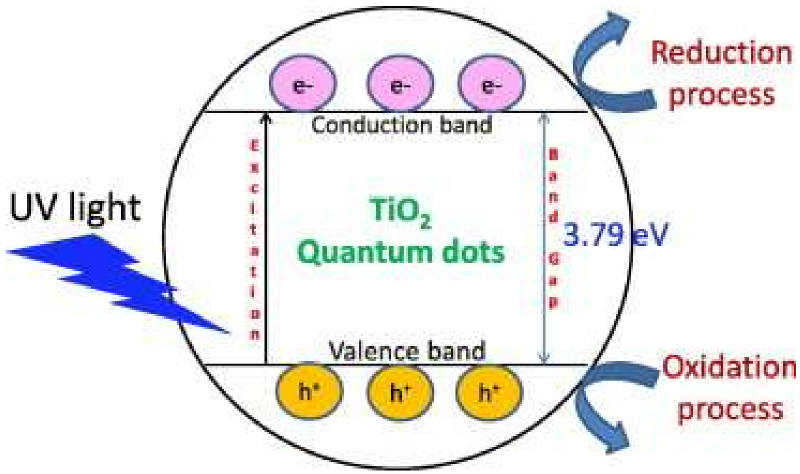
Currently, TiO_2 nano-particles have created a new approach for remarkable applications as an attractive multi-functional material. TiO_2 nano-particles have unique properties such as higher stabil- ity, long lasting, safe and broad-spectrum anti-biosis. TiO_2 nano-particles have been especially the center of attention for their photo-catalytic activities.

This makes Ti02 nano-particles applicable in many fields such as self-cleaning, anti-bacterial agent, UV protecting agent, environmental purification, water and air purifier, gas sensors, and high efficient solar cell. The photo-activity property is strongly related to the structure, micro-structure and the powder purification.

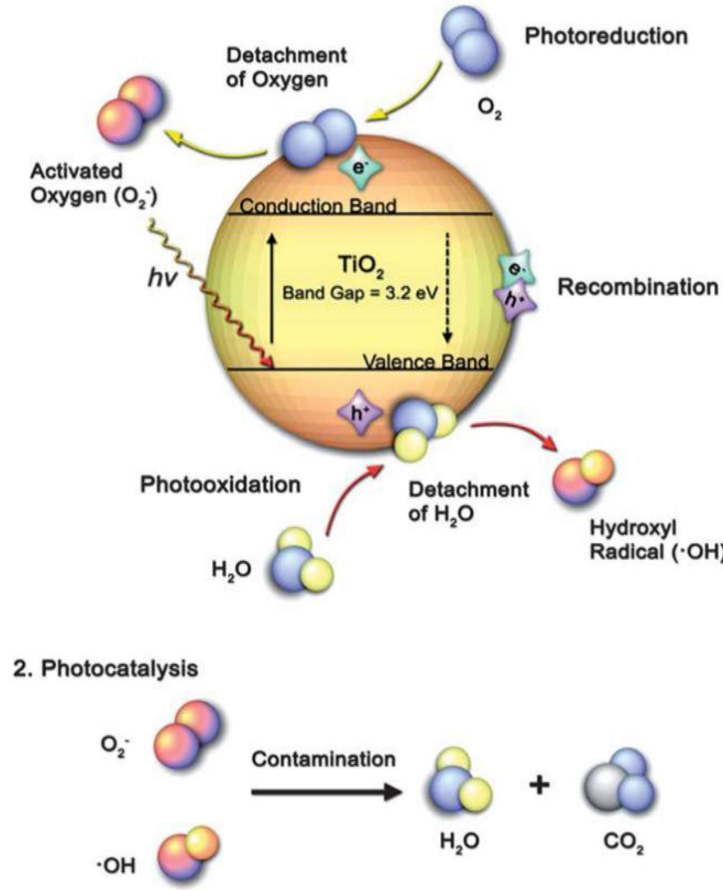
Three famous crystalline structures for TiO_2 have been known as anatase (tetragonal, a — 0.3785 nm, c: 0.9514 nm, band gap 3.2 ev which is equivalent to a wavelength of 388 nm), rutile (tetragonal, a—O.4593 nm, c: 0.2959 nm, band gap 3.02 eV) and brookite (orthorhombic, a—O.9182 nm, b:0.5456 nm, c: 0.5143 nm, band gap - 2.96 eV).

Titanium dioxide irradiation by light with more energy compared to its band gaps generates electron–hole pairs that induce redox reactions at the surface of the titanium dioxide. Consequently, electrons in TiO_2 jump from the valence band to the conduction band, and the electron (e−) and electric hole (h+) pairs are formed on the surface of the photo-catalyst. The created negative electrons and oxygen will combine into O_2−, the positive electric holes and water will generate hydroxyl radicals.

Ultimately, various highly active oxygen species can oxidize organic compounds of cell to carbon dioxide (CO_2) and water (H_2O). Thus, titanium dioxide can decompose common organic matters in the air such as odor molecules, bacteria and viruses.



UV light
Reduction process
Oxidation process
e-
e-
e-
Conduction band
Excitation
TiO$_2$
Quantum dots
Band Gap
3.79 eV
Valence band
h+
h+
h+



Photoreduction
Detachment of Oxygen
O$_2$
Activated Oxygen (O$_2^-$)
e-
Conduction Band
hv
TiO$_2$
Band Gap = 3.2 eV
Recombination
e-
h+
Valence Band
h+
Photooxidation
Detachment of H$_2$O
H$_2$O
Hydroxyl Radical (·OH)
2. Photocatalysis
O$_2^-$
·OH
Contamination
H$_2$O
+
CO$_2$

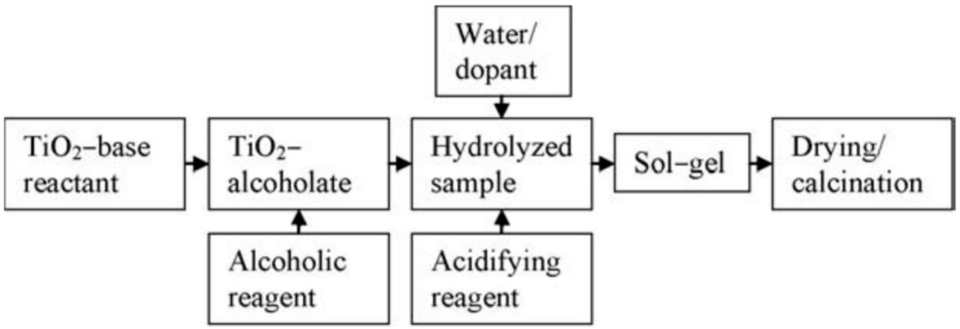
Rutile is the mostly used form in the pigments industry.

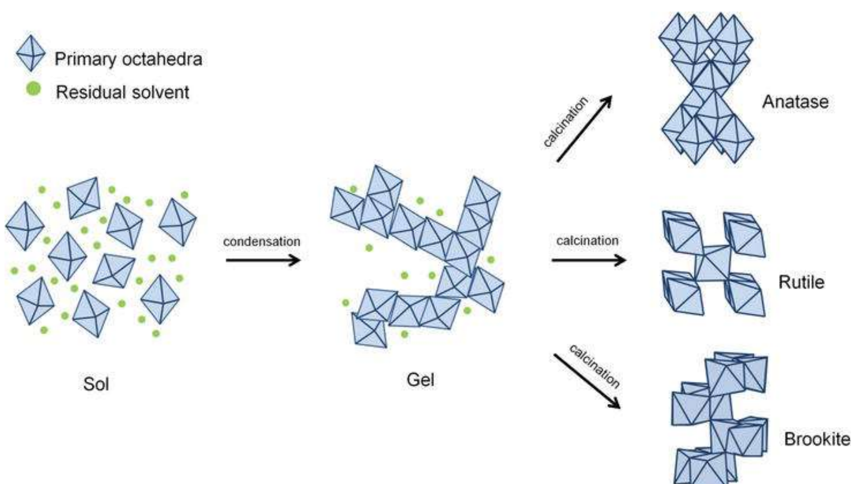
The band-gap energy of anatase is higher than that of rutile. [anatase has a band gap of about 3.6 eV, and brookite a band gap of 3.4 eV, which is confirmed by Alotaibi. Rutile was measured to have a larger band gap (3.3 − 3.5 eV) than is usually found in the literature.]

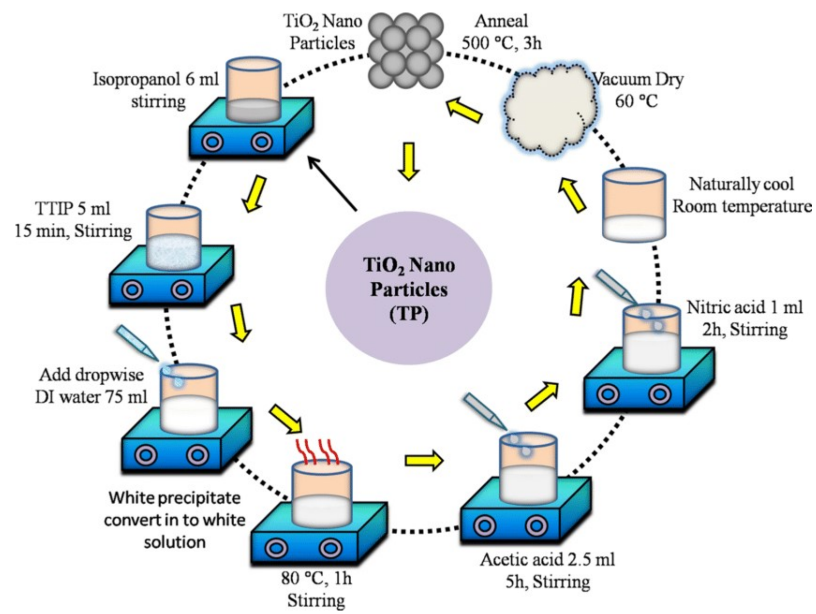
However, a wide range of band-gap energies have been recorded for both anatase and rutile crystalline structure. Addition of Zr4+ and Si4+ into the titania structure increases the anatase stability and the anatase to rutile transformation (ART).

A number of techniques have been employed for production of TiO_2 nano-particles. One of the most common methods is the sol–gel processing. Fu et al. have applied the sol–gel method to fabricate nano-particles of TiO_2 in its anatase form. The particle size is reported to be sensitive to solution pH and the rate of addition of isopropoxide.

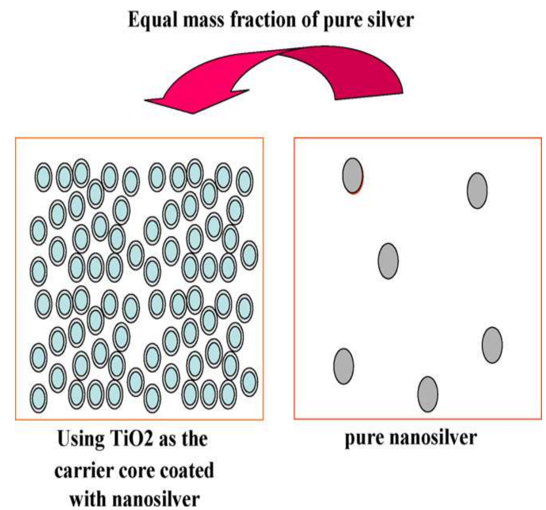
Flow diagram of sol-gel process of TiO_2



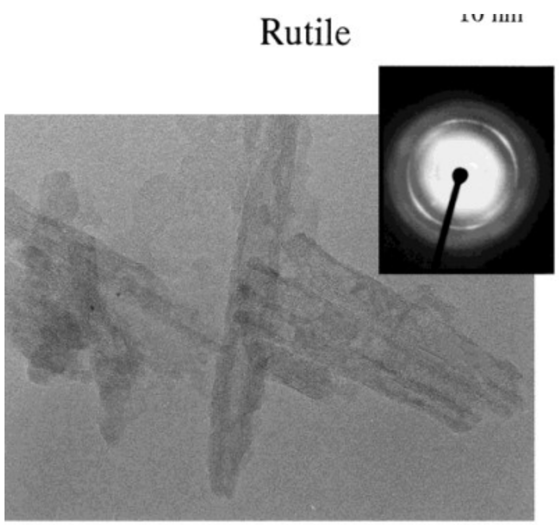




Metallic TiO_2 nano-composites. Since TiO_2 has a relatively high energy band gap (3.2 V), TiO_2 nano-particles can only be excited by high energy UV irradiation with a wavelength shorter than 387.5 nm. Many investigations confirm that the addition of noble metals such as gold and silver increases the photo-catalytic activities of titanium dioxide by extending the light absorption range of TiO_2 from UV to visible light . As an example, Ag can act as the electron traps aiding electron–hole separation, and also facilitates electron excitation by creating a local electric field . When the achievements of anti-bacterial activity are considered, surface coating of nano-silver on titanium dioxide also maximizes the number of silver nano-particle per unit area on the surface compared to using equal mass fraction of pure silver (Fig. ->). **Moreover many researchers have tried to increase the attainable surface activation sites by either using nanocrystalline materials or making porous micro-structure. Thus, the photo-catalytic performance can be enhanced.**



Kim et al. employed hydrazine hydrate as a reducing agent for deposition of Ag nano-particles via chemical reduction on the surface of TiO_2 nano-particles. Silver with a particle size of 5 nm had been formed on the TiO_2 surfaces. By increasing the Ag fraction, the UV–vis absorption spectrum shifted to long wavelengths (>400 nm) resulting from the interaction of Ag and TiO_2 particles.



Titania nanotubes (TNTs).

Titania nanotubes (TNTs). Nanotubues have a large surface area. Titania nanotubes (TNTs) have large surface area and particular tubular structure. In addition, their potential breakthrough in high efficient dye-sensitized solar cells has been mentioned. The decomposition of gases, effects of electronic field on optical properties of nano-TiO_2, their structural and optical properties, effects of UV irradiation on hydrophilicity of TiO_2 treated fabric, anti-creasing of cellulose with multi-functional organic acid (carboxylic acids) using catalytic effects of TiO_2 under UV irradiation and UV protecting effect of TiO_2 for fabric have been explored.

A new method for the synthesis of titanium oxide (TiO_2) nanotubes. When anatase-phase- or rutile-phase-containing TiO_2 was treated with an aqueous solution of 5–10 M NaOH for 20 h at 110 deg C and then with HCl aqueous solution and distilled water, needle-shaped TiO_2 products were obtained (diameter » 8 nm, length » 100 nm). The needle-shaped products are nanotubes with inner diameters of approximately 5 nm and outer diameters of approximately 8 nm.